## Space Weather Technical Forecast

Issued on Sunday 22 December 2024 at 13:21 Local

**This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales**

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**Space Weather Forecast Headline: R1/R2 Likely. Uncertainty in geomagnetic forecast.**

**Analysis of Space Weather Activity over past 24 hours**

**Solar Activity:** Solar activity has been Moderate due to a single impulsive M1.0 flare at 22/0410 UTC, likely from AR3932 in the southeast.

There are currently eleven sunspot regions on the visible disc. The southeastern quadrant remains the focus of main solar activity, containing a cluster of the three largest regions (AR3928, AR3932 and AR3933), all of which are moderately wide bipolar spot groups, showing some degree of magnetic complexity. AR3926 in the southwest has recently seen a small opposite polarity spot develop, and is now a simple bipolar group. AR3934 in the far northeast is also appearing to be a fairly wide spot group as it rotates more into view. Other remaining regions are relatively small, stable and magnetically simple.

A filament lift-off from the northeast and associated CME from late in the UTC day on 20 Dec was modelled and gives a potential peripheral glance around 24/0000 UTC.

A number of other CMEs have been observed in available imagery during the period. Analysis of these suggests none have an Earth directed component, however confidence in the complex number of CMEs is currently low.

**Solar Wind / Geomagnetic Activity:** Solar winds, observed at L1 by DSCOVR and ACE have shown Elevated conditions with uncertain cause - perhaps coronal hole influence from CH01/-. The solar wind speeds have averaged around 530 km/s, but have reached a peak of 625 km/s. Density was average to below average. The Interplanetary Magnetic Field (IMF), Bt, was Moderate at times, but generally remained between 6-9nT. The north-south component, Bz, varied weakly throughout, ranging between +8 and -7nT. Geomagnetic activity was Quiet to Unsettled (Kp2-3).

**Energetic Particles / Solar Radiation:** High energy proton flux (greater than 10MeV) observed by GOES18 gradually increased early in the period before levelling off, remaining sub-S1 (10pfu), reaching 5.1pfu at 21/1820UTC.

High energy electron flux (greater than 2MeV) observed by GOES16 peaked at Moderate levels, with 757pfu observed at 21/1955UTC. The associated 24-hour fluence was below the Active (1e8 integrated flux) threshold. The 22/0001UTC observation was 2.07e7 integrated pfu, with a slight rising trend.

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**Four-Day Space Weather Forecast Summary**

**Solar Activity:** Isolated M-class flares are Likely, mainly from AR3928 or AR3932, perhaps bolstered slightly beyond the current UTC weekend by returning regions. A Slight Chance of isolated X-class flares is maintained throughout.

**Solar Wind / Geomagnetic Activity:** A filament lift-off from the northeast from late in the UTC day on 20 Dec was modelled and gives a potential peripheral glance around 24/0000 UTC. No other Earth-directed CMEs appear in the forecast, however the number of CMEs over the past few days means confidence is low.

Overall, conditions are likely to remain Quiet to Unsettled. Given current Elevated solar wind speeds, there is a chance of Active conditions through the period, tentatively peaking around days 2 and 3 (23-24 Dec) due to CH01/- and possible glancing influence from 20 Dec CME, with a slight chance of G1 Minor Geomagnetic Storms.

**Energetic Particles / Solar Radiation:** There is a Chance of S1-level or greater enhancements through the current UTC weekend due to current slightly enhanced near-Earth proton counts. This risk should relax back in the absence of any significant flares, with most of the risk from the front-side then tied to the westward advance of the cluster of southeastern sunspot regions.

The high energy electron forecast carries lower-than-average confidence due to inherited uncertainties from the geomagnetic forecast, especially surrounding any possible onset of CH01/-, and potential glancing CME influence. Overall, the chances of disturbances in the period are higher than average, with perhaps a gradually rising Slight Chance perhaps the best representation.

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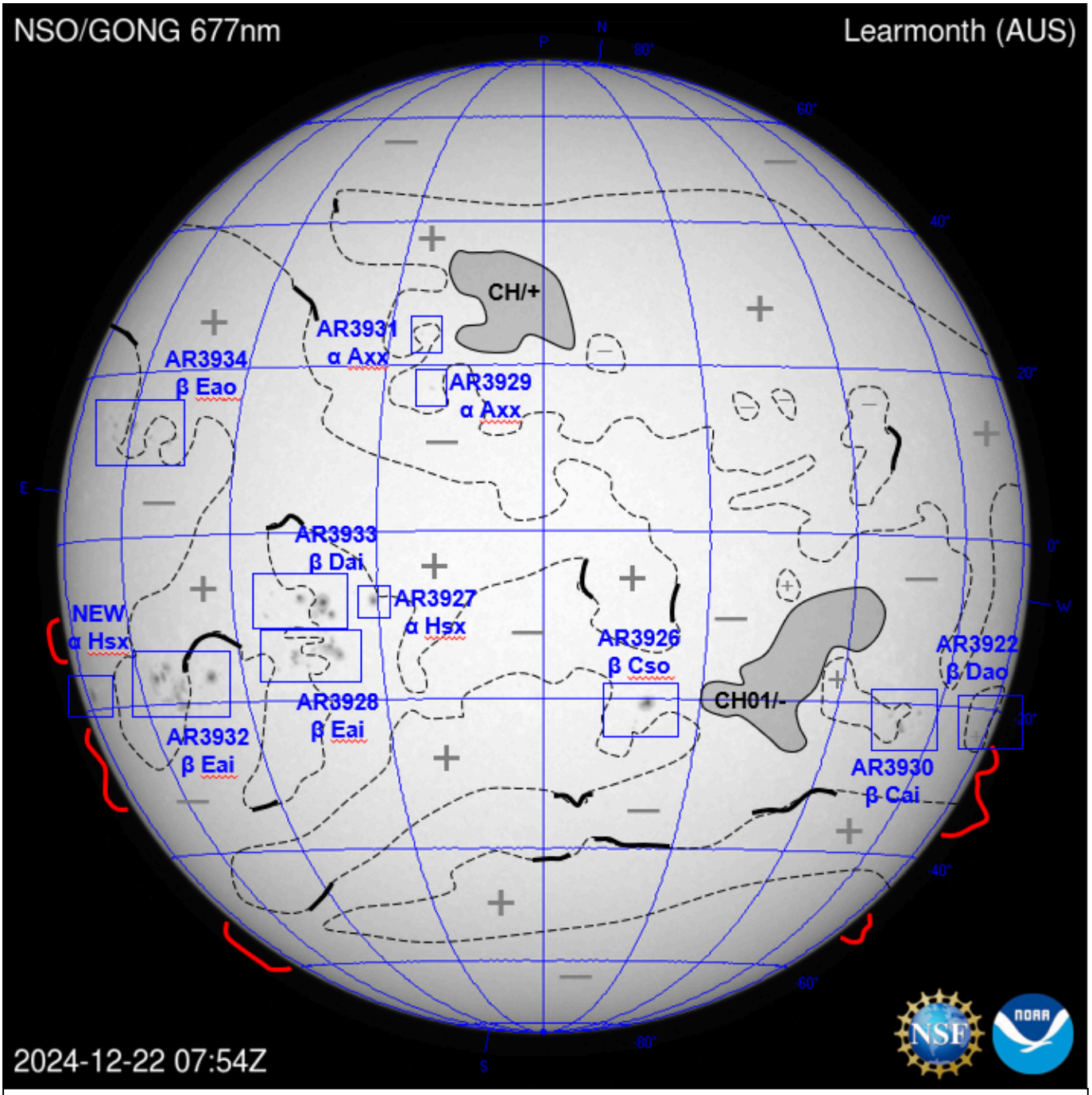
**Figure 1: Solar Synoptic Map valid 22/0800 UTC**




**Key:** Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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## Geomagnetic Storms

A filament lift-off from the northeast from late in the UTC day on 20 Dec was modelled and gives a potential peripheral glance around 24/0000 UTC. There are also a number of other CMEs (coronal mass ejections) observed during the period which have now been analysed, including two CMEs off the southwest limb early 22 Dec, but current results suggest they are all directed off the Sun-Earth line.

Current solar winds are Elevated via an uncertain mechanism, potentially early connection to CH01/- given the negative phi angle. The coronal hole itself has shown changes in shape over the past three or four days, with some northwestward elongation perhaps taking places, making onset forecasting more complicated. Flux looping to its immediate west in GOES SUVI 195 imagery isn't helping by potentially masking any leading portion of this hole, although the main bulk of the feature still seems rather far east for current observations, and there may be an alternative cause. This is the main forecast feature due in the period, and the fact that it may already be in course lowers confidence for the forecast as a whole. CH01/- itself is a non-persistent feature, further exacerbating the issue.

Overall, conditions are likely to remain Quiet to Unsettled. Given current Elevated solar wind speeds, there is a chance of Active conditions through the period, tentatively peaking around days 2 and 3 (23-24 Dec) due to CH01/- and possible glancing influence from 20 Dec CME, with a slight chance of G1 Minor Geomagnetic Storms. A mitigating factor against larger effects from any coronal hole is being near the semi-annual minimum coronal hole geoeffectivity near the solstice.

| Geomagnetic Storm Probability (Exceedance) | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| Minor or Moderate | G1 to G2 | No | 5 | 10 | 20 | 5 |
| Strong | G3 | No | 1 | 1 | 5 | 1 |
| Severe | G4 | No | 1 | 1 | 1 | 1 |
| Extreme | G5 | No | 1 | 1 | 1 | 1 |

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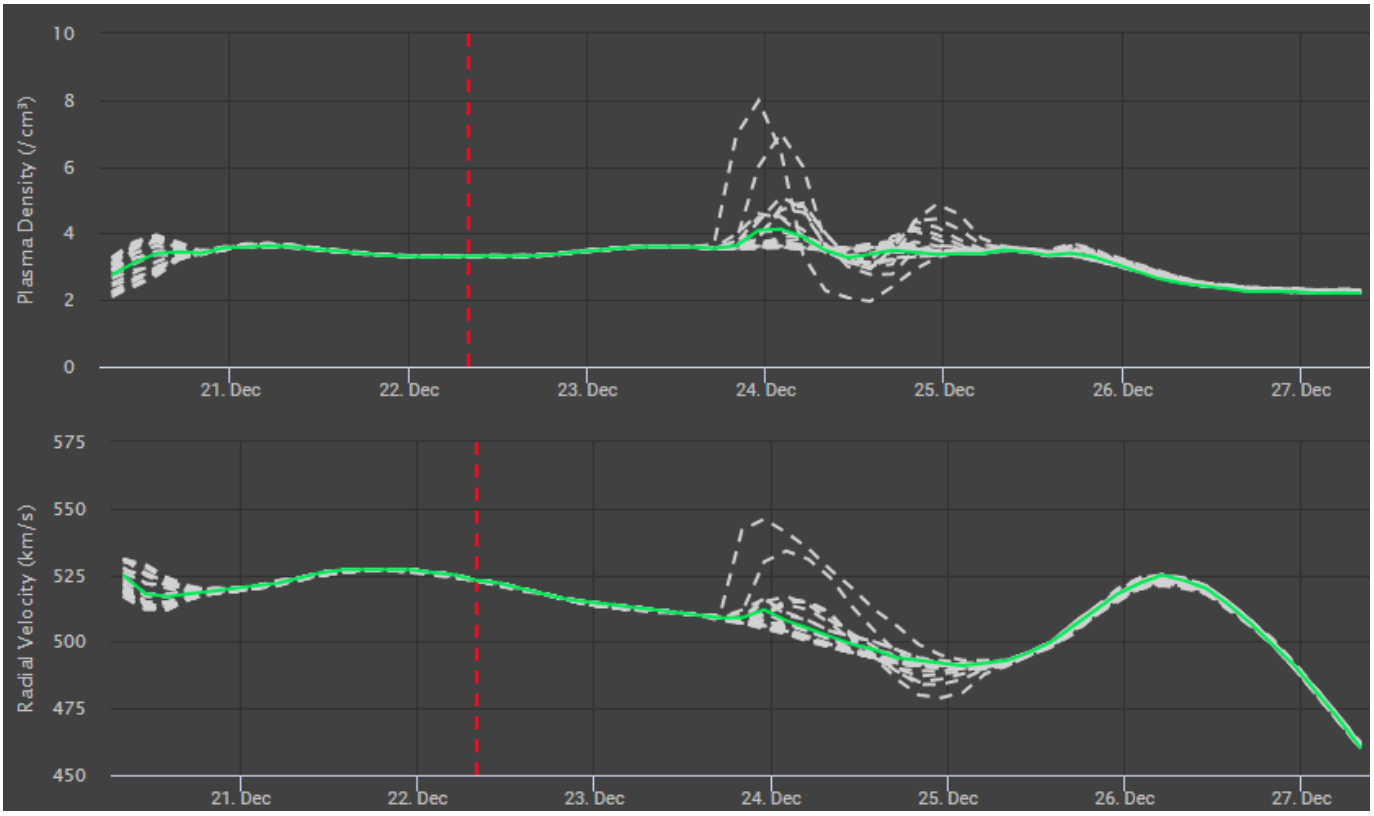
**Geomagnetic Activity - Earthbound Coronal Mass Ejections**

| Date/time 21.5R⊙ (UTC) | Halo: Full or Partial | Source | Source Location | Estimated Speed (km/s) | Estimated Arrival Time (UTC) | Comments |
|---|---|---|---|---|---|---|
| 21/0535 UTC | Partial | Filament | NE quadrant | 532 | 24/0000 UTC | Possible glance but low confidence. |

**Figure 2: MOSWOC Ensemble model, showing potential for CME glance around 24/0000 UTC.**

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## Radio Blackouts - X-Ray Flares

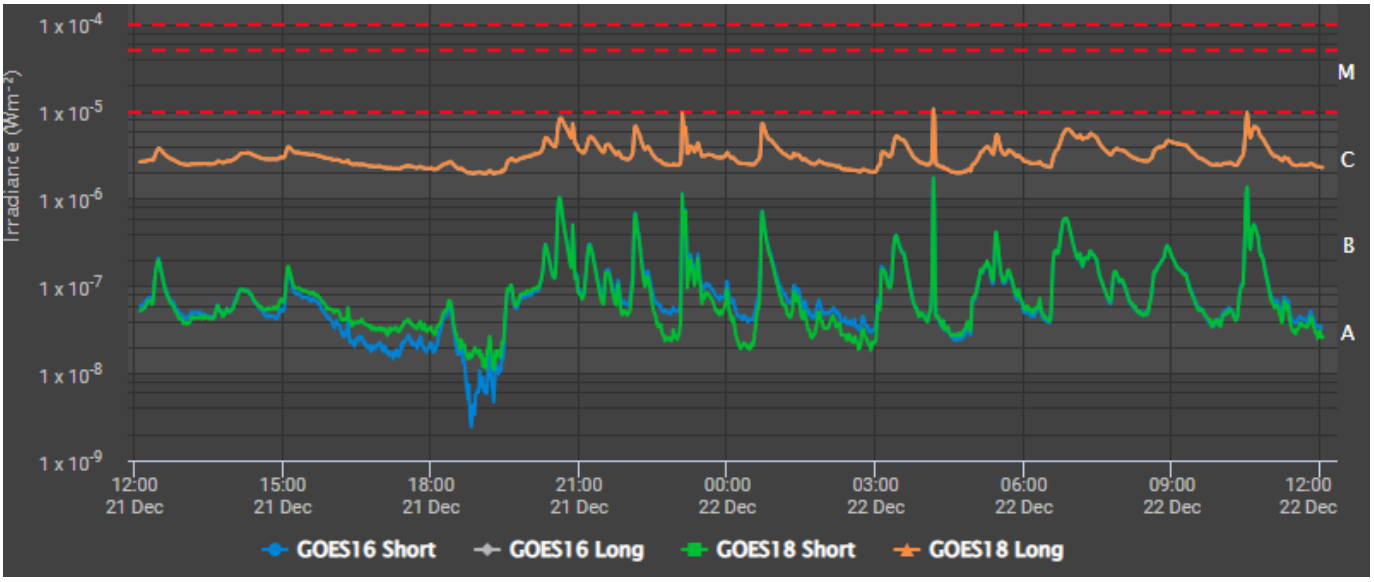
Solar activity has been Moderate due to a single impulsive M1.0 flare at 22/0410 UTC, likely from AR3932 in the southeast. Further isolated M-class flares are considered likely, with a slight chance of X-class flares. The most likely source being from the grouping of regions in the southeast quadrant.

There are currently eleven sunspot regions on the visible disc, with one new as yet unnumbered region on the southeast limb. The southeastern quadrant remains the focus of main solar activity, containing a cluster of the three largest regions (AR3928, AR3932 and AR3933), all of which are moderately wide bipolar spot groups, showing some degree of magnetic complexity. AR3926 in the southwest has recently seen a small opposite polarity spot develop, and is now a simple bipolar group. AR3934 in the northeast is also appearing to be a fairly wide spot group as it rotates more into view. Other remaining regions are relatively small, stable and magnetically simple.

There is the potential for some further eastern limb returning regions over the next day or so, perhaps foremost amongst these being Ex-AR3910, with Ex-AR3912 then also due Monday 23 December. The potential of this is the reason the flare risk increases slightly through the period.

| X-Ray Flares | Level | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) | Day 2 (00-24 UTC) | Day 3 (00-24 UTC) | Day 4 (00-24 UTC) |
|---|---|---|---|---|---|---|
| Probability | | | (%) | (%) | (%) | (%) |
| Active | R1-R2 (M Class) | Yes | 65 | 70 | 75 | 75 |
| Very Active | R3-R5 (X Class) | No | 10 | 10 | 10 | 10 |

**Figure 3: GOES-16 & -18 X-ray flux.**

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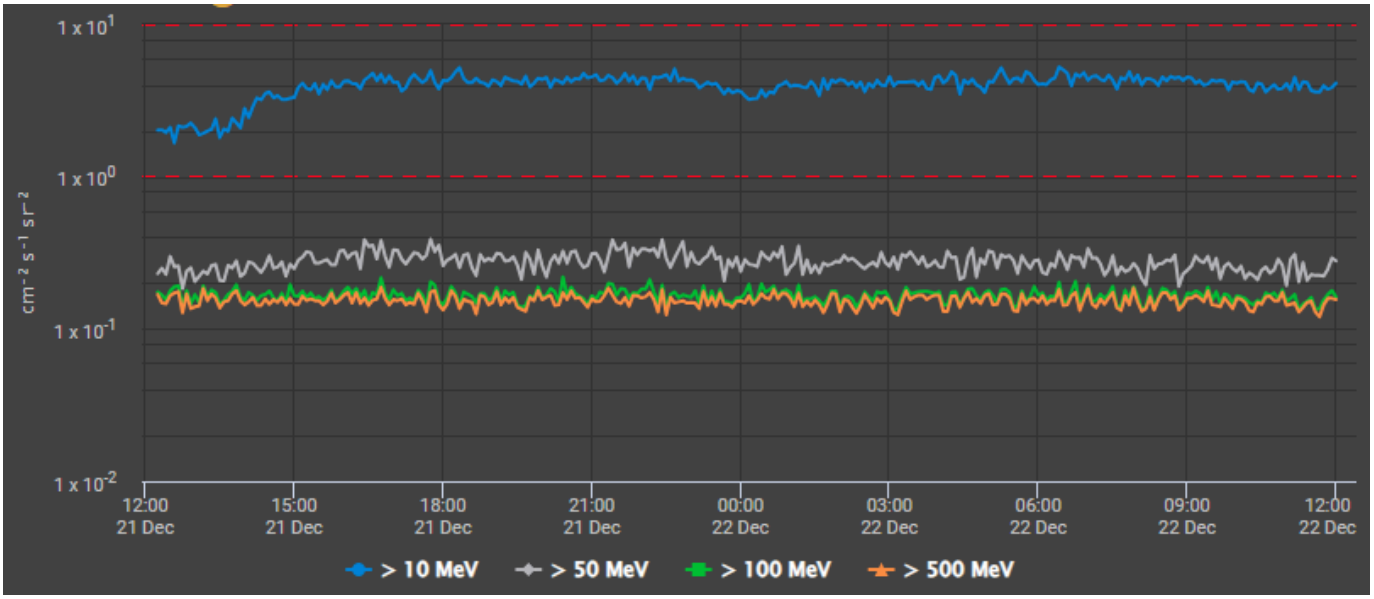
## Solar Radiation Storms (High Energy Protons)

The source of the currently observed enhancement in the near-Earth environment is uncertain, but given the damped rise and soft spectrum, an eastern solar hemisphere or far-sided source seems most likely, perhaps from 19 December with possible further additions since. The chances of S1-scale or greater events are currently slightly raised as a result of the increased counts, however barring further additions, a relaxing back towards the raw disc value of 15% is forecast for a time. An increasing trend is then anticipated as the main southeastern sunspot regions advance westwards.

| Radiation Storms Probability (Exceedance) | Level ($cm^{-2}sr^{-1}s^{-1}$) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) (%) | Day 2 (00-24 UTC) (%) | Day 3 (00-24 UTC) (%) | Day 4 (00-24 UTC) (%) |
|---|---|---|---|---|---|---|
| **Active** | **≥ S1** | No | 20 | 15 | 20 | 20 |
| **Very Active** | **≥ S3 *** | No | 1 | 1 | 1 | 1 |
| * S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$) | | | | | | |

**Figure 4: GOES-18 Proton flux.**



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## High Energy Electrons (≥ 2MeV)

The current high energy electron flux is oscillating between background and moderate levels. This trend may accelerate at GEO given recently observed Elevated solar winds and periods of Unsettled geomagnetic activity, with the period as a whole carrying low confidence as a result of an uncertain CME picture and non-recurrent - and in fact possibly already underway - coronal hole.

MOSWOC REFM gives a reasonable guide, although does not represent either any impinging CME activity nor non-persistent coronal holes, and as such the forecast carries low confidence as already mentioned.

All considered, there is a gradually rising Slight Chance of 24-hour fluence reaching Active.

| GEO Electron Environment | Level ($cm^{-2}sr^{-1}$ $day^{-1}$) | Past 24 Hours (Yes/No) | Day 1 (00-24 UTC) | Day 2 (00-24 UTC) | Day 3 (00-24 UTC) | Day 4 (00-24 UTC) |
|---|---|---|---|---|---|---|
| Probability (Exceedance) | | | (%) | (%) | (%) | (%) |
| Active | ≥ 2 MeV ≥ $1\times10^{8}$ | No | 5 | 5 | 10 | 10 |
| Very Active | ≥ 2 MeV ≥ $1\times10^{9}$ | No | 1 | 1 | 1 | 1 |

**Figure 5: GOES-16 Electron flux.**

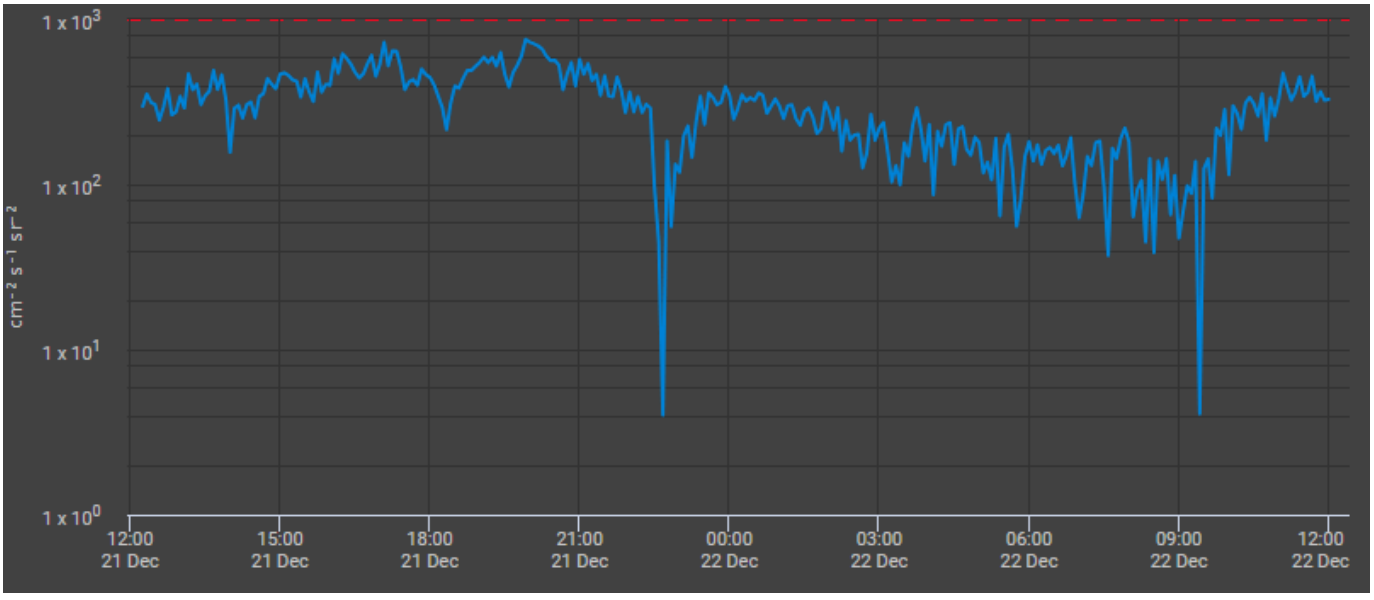


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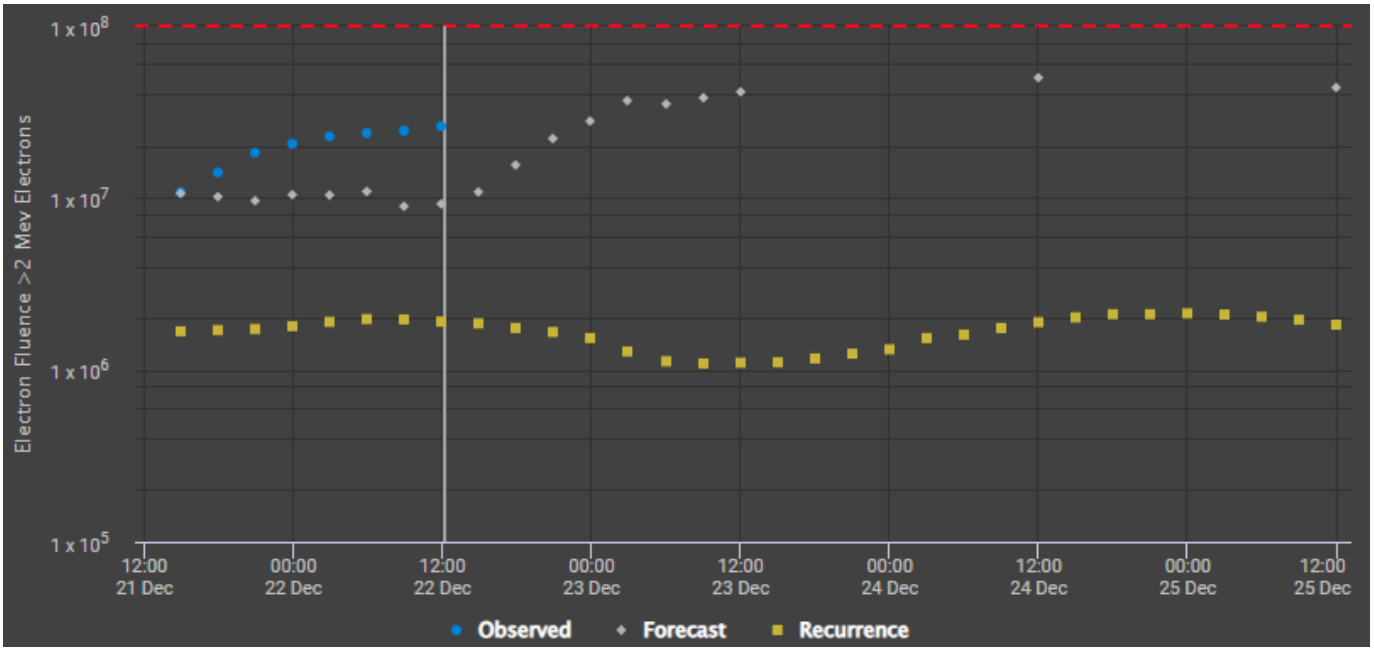
**Figure 6: MOSWOC REFM.**



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